

**What Is Claimed Is:**

- 1        1. A method to facilitate auto-alignment of images for defect  
2 inspection and defect analysis, comprising:
  - 3        receiving a reference image and a test image;
  - 4        creating a horizontal cut line across the reference image;
  - 5        choosing a vertical feature on the reference image with a specified width  
6 along the horizontal cut line;
  - 7        determining that the vertical feature substantially maintains the specified  
8 width over a specified range above and below the horizontal cut line;
  - 9        locating a corresponding vertical feature on the test image;
  - 10       creating a vertical cut line across the reference image;
  - 11       choosing a horizontal feature on the reference image with the specified  
12 width along the vertical cut line;
  - 13       determining that the horizontal feature substantially maintains the  
14 specified width over a specified range left and right of the vertical cut line;
  - 15       locating a corresponding horizontal feature on the test image; and
  - 16       aligning the reference image and the test image by aligning the vertical  
17 feature on the reference image with the corresponding vertical feature on the test  
18 image and aligning the horizontal feature on the reference image with the  
19 corresponding horizontal feature on the test image.
- 1        2. The method of claim 1, further comprising:
  - 2        creating a first plurality of horizontal cut lines across the reference image;
  - 3        choosing the horizontal cut line including at least one vertical feature from  
4 the first plurality of horizontal cut lines;
  - 5        creating a first plurality of vertical cut lines across the reference image;

6           choosing the vertical cut line including at least one horizontal feature from  
7   the first plurality of vertical cut lines;  
8           creating a second plurality of horizontal cut lines across the test image;  
9           choosing a test horizontal cut line from the second plurality of horizontal  
10   cut lines, by iterating through the second plurality of horizontal cut lines until the  
11   test horizontal cut line includes a test vertical feature with a substantially same  
12   horizontal width and same neighborhood characteristics as the vertical feature;  
13           creating a second plurality of vertical cut lines across the test image;  
14           choosing a test vertical cut line from the second plurality of vertical cut  
15   lines, by iterating through the second plurality of vertical cut lines until the test  
16   vertical cut line includes a test horizontal feature with a substantially same vertical  
17   width and same neighborhood characteristics as the horizontal feature;  
18           aligning the reference image and the test image in a horizontal direction  
19   using the horizontal cut line and the test horizontal cut line; and  
20           aligning the reference image and the test image in a vertical direction using  
21   the vertical cut line and the test vertical cut line.

1           3.       The method of claim 2, further comprising aligning the reference  
2   image and the test image using edges of the vertical feature and the horizontal  
3   feature.

1           4.       The method of claim 2, further comprising aligning the reference  
2   image and the test image using midpoints of the vertical feature and the horizontal  
3   feature.

1           5.       The method of claim 1, wherein the reference image includes one  
2   of:

3                   an inspection mask generated by mask inspection equipment;  
4                   a mask image from a database;  
5                   a wafer image; and  
6                   a die image.

1                 6.       The method of claim 1, wherein the test image includes one of:  
2                   an inspection mask generated by mask inspection equipment;  
3                   a mask image from a database;  
4                   a wafer image; and  
5                   a die image.

1                 7.       The method of claim 1, further comprising:  
2                   clustering feature widths within the reference image; and  
3                   choosing a width that occurs most often as the specified width.

1                 8.       A computer-readable storage medium storing instructions that  
2                   when executed by a computer cause the computer to perform a method to  
3                   facilitate auto-alignment of images for defect inspection and defect analysis, the  
4                   method comprising:  
5                   receiving a reference image and a test image;  
6                   creating a horizontal cut line across the reference image;  
7                   choosing a vertical feature on the reference image with a specified width  
8                   along the horizontal cut line;  
9                   determining that the vertical feature substantially maintains the specified  
10                  width over a specified range above and below the horizontal cut line;  
11                  locating a corresponding vertical feature on the test image;  
12                  creating a vertical cut line across the reference image;

13        choosing a horizontal feature on the reference image with the specified  
14    width along the vertical cut line;  
15        determining that the horizontal feature substantially maintains the  
16    specified width over a specified range left and right of the vertical cut line;  
17        locating a corresponding horizontal feature on the test image; and  
18        aligning the reference image and the test image by aligning the vertical  
19    feature on the reference image with the corresponding vertical feature on the test  
20    image and aligning the horizontal feature on the reference image with the  
21    corresponding horizontal feature on the test image.

1            9.        The computer-readable storage medium of claim 8, the method  
2    further comprising:  
3        creating a first plurality of horizontal cut lines across the reference image;  
4        choosing the horizontal cut line including at least one vertical feature from  
5    the first plurality of horizontal cut lines;  
6        creating a first plurality of vertical cut lines across the reference image;  
7        choosing the vertical cut line including at least one horizontal feature from  
8    the first plurality of vertical cut lines;  
9        creating a second plurality of horizontal cut lines across the test image;  
10        choosing a test horizontal cut line from the second plurality of horizontal  
11    cut lines, by iterating through the second plurality of horizontal cut lines until the  
12    test horizontal cut line includes a test vertical feature with a substantially same  
13    horizontal width and same neighborhood characteristics as the vertical feature;  
14        creating a second plurality of vertical cut lines across the test image;  
15        choosing a test vertical cut line from the second plurality of vertical cut  
16    lines, by iterating through the second plurality of vertical cut lines until the test

17 vertical cut line includes a test horizontal feature with a substantially same vertical  
18 width and same neighborhood characteristics as the horizontal feature;  
19 aligning the reference image and the test image in a horizontal direction  
20 using the horizontal cut line and the test horizontal cut line; and  
21 aligning the reference image and the test image in a vertical direction using  
22 the vertical cut line and the test vertical cut line.

1 10. The computer-readable storage medium of claim 9, the method  
2 further comprising aligning the reference image and the test image using edges of  
3 the vertical feature and the horizontal feature.

1 11. The computer-readable storage medium of claim 9, the method  
2 further comprising aligning the reference image and the test image using  
3 midpoints of the vertical feature and the horizontal feature.

1 12. The computer-readable storage medium of claim 8, wherein the  
2 reference image includes one of:  
3 an inspection mask generated by mask inspection equipment;  
4 a mask image from a database;  
5 a wafer image; and  
6 a die image.

1 13. The computer-readable storage medium of claim 8, wherein the  
2 test image includes one of:  
3 an inspection mask generated by mask inspection equipment;  
4 a mask image from a database;  
5 a wafer image; and

6 a die image.

1 14. The computer-readable storage medium of claim 8, the method  
2 further comprising:  
3 clustering feature widths within the reference image; and  
4 choosing a width that occurs most often as the specified width.

1 15. An apparatus to facilitate auto-alignment of images for defect  
2 inspection and defect analysis, comprising:  
3 a receiving mechanism that is configured to receive a reference image and  
4 a test image;  
5 a creating mechanism that is configured to create a horizontal cut line  
6 across the reference image;  
7 wherein the creating mechanism is further configured to create a vertical  
8 cut line across the reference image;  
9 a choosing mechanism that is configured to choose a vertical feature on  
10 the reference image with a specified width along the horizontal cut line;  
11 wherein the choosing mechanism is further configured to choose a  
12 horizontal feature on the reference image with the specified width along the  
13 vertical cut line;  
14 a determining mechanism that is configured to determine that the vertical  
15 feature substantially maintains the specified width over a specified range above  
16 and below the horizontal cut line;  
17 wherein the determining mechanism is further configured to determine  
18 that the horizontal feature substantially maintains the specified width over a  
19 specified range left and right of the vertical cut line;

20           a locating mechanism that is configured to locate a corresponding vertical  
21        feature on the test image;  
22           wherein the locating mechanism is further configured to locate a  
23        corresponding horizontal feature on the test image; and  
24           an aligning mechanism that is configured to align the reference image and  
25        the test image by aligning the vertical feature on the reference image and the  
26        corresponding vertical feature on the test image and by aligning the horizontal  
27        feature on the reference image and the corresponding horizontal feature on the test  
28        image.

1           16.    The apparatus of claim 15, wherein  
2        the creating mechanism is further configured to create a first plurality of  
3        horizontal cut lines across the reference image;  
4           the choosing mechanism is further configured to choose the horizontal cut  
5        line including at least one vertical feature from the first plurality of horizontal cut  
6        lines;  
7           the creating mechanism is further configured to create a first plurality of  
8        vertical cut lines across the reference image;  
9           the choosing mechanism is further configured to choose the vertical cut  
10       line including at least one horizontal feature from the first plurality of vertical cut  
11       lines;  
12           the creating mechanism is further configured to create a second plurality of  
13       horizontal cut lines across the test image;  
14           the choosing mechanism is further configured to choose a test horizontal  
15       cut line from the second plurality of horizontal cut lines, by iterating through the  
16       second plurality of horizontal cut lines until the test horizontal cut line includes a

17 test vertical feature with a substantially same horizontal width and same  
18 neighborhood characteristics as the vertical feature;  
19 the creating mechanism is further configured to create a second plurality of  
20 vertical cut lines across the test image;  
21 the choosing mechanism is further configured to choose a test vertical cut  
22 line from the second plurality of vertical cut lines, by iterating through the second  
23 plurality of vertical cut lines until the test vertical cut line includes a test  
24 horizontal feature with a substantially same vertical width and same neighborhood  
25 characteristics as the horizontal feature;  
26 the aligning mechanism is further configured to align the reference image  
27 and the test image in a horizontal direction using the horizontal cut line and the  
28 test horizontal cut line; and  
29 the aligning mechanism is further configured to align the reference image  
30 and the test image in a vertical direction using the vertical cut line and the test  
31 vertical cut line.

1 17. The apparatus of claim 16, wherein the aligning mechanism is  
2 further configured to align the reference image and the test image using edges of  
3 the vertical feature and the horizontal feature.

1 18. The apparatus of claim 16, wherein the aligning mechanism is  
2 further configured to align the reference image and the test image using midpoints  
3 of the vertical feature and the horizontal feature.

1 19. The apparatus of claim 15, wherein the reference image includes  
2 one of:  
3 an inspection mask generated by mask inspection equipment;

4           a mask image from a database;  
5           a wafer image; and  
6           a die image.

1           20.    The apparatus of claim 15, wherein the test image includes one of:  
2           an inspection mask generated by mask inspection equipment;  
3           a mask image from a database;  
4           a wafer image; and  
5           a die image.

1           21.    The apparatus of claim 15, further comprising:  
2           a clustering mechanism that is configured to cluster feature widths within  
3           the reference image; and  
4           wherein the choosing mechanism is further configured to choose a width  
5           that occurs most often as the specified width.

1           22.    A system to facilitate auto-alignment of images for defect  
2           inspection and defect analysis, comprising:  
3           receiving means for receiving a reference image and a test image;  
4           creating means for creating a horizontal cut line across the reference  
5           image;  
6           choosing means for choosing a vertical feature on the reference image with  
7           a specified width along the horizontal cut line;  
8           determining means for determining that the vertical feature substantially  
9           maintains the specified width over a specified range above and below the  
10          horizontal cut line;

11       locating means for locating a corresponding vertical feature on the test  
12 image;  
13       creating means for creating a vertical cut line across the reference image;  
14       choosing means for choosing a horizontal feature on the reference image  
15 with the specified width along the vertical cut line;  
16       determining means for determining that the horizontal feature substantially  
17 maintains the specified width over a specified range left and right of the vertical  
18 cut line;  
19       locating means for locating a corresponding horizontal feature on the test  
20 image; and  
21       aligning means for aligning the reference image and the test image by  
22 aligning the vertical feature on the reference image to the corresponding vertical  
23 feature on the test image and by aligning the horizontal feature on the reference  
24 image and the corresponding horizontal feature on the test image.

1       23.    The system of claim 22, further comprising:  
2       creating means for creating a first plurality of horizontal cut lines across  
3 the reference image;  
4       choosing means for choosing the horizontal cut line including at least one  
5 vertical feature from the first plurality of horizontal cut lines;  
6       creating means for creating a first plurality of vertical cut lines across the  
7 reference image;  
8       choosing means for choosing the vertical cut line including at least one  
9 horizontal feature from the first plurality of vertical cut lines;  
10       creating means for creating a second plurality of horizontal cut lines across  
11 the test image;

12        choosing means for choosing a test horizontal cut line from the second  
13    plurality of horizontal cut lines, by iterating through the second plurality of  
14    horizontal cut lines until the test horizontal cut line includes a test vertical feature  
15    with a substantially same horizontal width as the vertical feature and a  
16    substantially same neighboring characteristics on the test vertical feature as  
17    determined by width;  
18        creating means for creating a second plurality of vertical cut lines across  
19    the test image;  
20        choosing means for choosing a test vertical cut line from the second  
21    plurality of vertical cut lines, by iterating through the second plurality of vertical  
22    cut lines until the test vertical cut line includes a test horizontal feature with a  
23    substantially same vertical width as the horizontal feature and a substantially same  
24    neighboring characteristics on the test horizontal feature as determined by width;  
25        aligning means for aligning the reference image and the test image in a  
26    horizontal direction using the horizontal cut line and the test horizontal cut line;  
27    and  
28        aligning means for aligning the reference image and the test image in a  
29    vertical direction using the vertical cut line and the test vertical cut line.

1        24.    The system of claim 23, further comprising aligning means for  
2    aligning the reference image and the test image using edges of the vertical feature  
3    and the horizontal feature.

1        25.    The system of claim 23, further comprising aligning means for  
2    aligning the reference image and the test image using midpoints of the vertical  
3    feature and the horizontal feature.

1           26. The system of claim 22, wherein the reference image includes one  
2 of:

3           an inspection mask generated by mask inspection equipment;  
4           a mask image from a database;  
5           a wafer image; and  
6           a die image.

1           27. The system of claim 22, wherein the test image includes one of:  
2           an inspection mask generated by mask inspection equipment;  
3           a mask image from a database;  
4           a wafer image; and  
5           a die image.

1           28. The system of claim 22, further comprising:  
2           clustering means for clustering feature widths within the reference image;  
3           and  
4           choosing means for choosing a width that occurs most often as the  
5           specified width.